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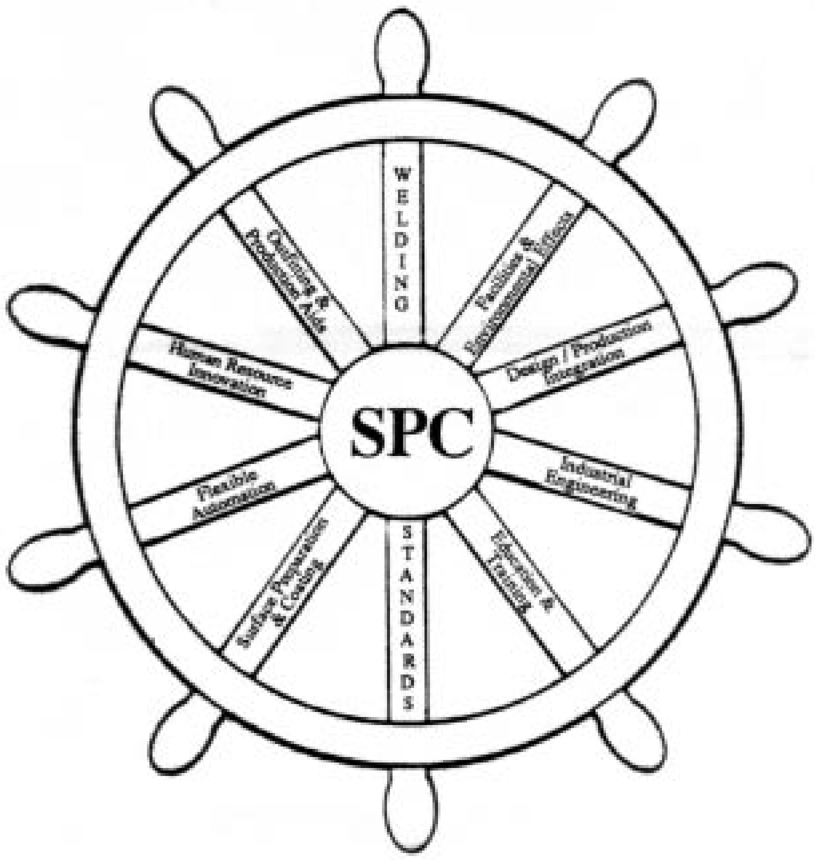

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Development of Design and Fabrication Method of Thin Steel Plate Structure and its Application to a Passenger Ship

7A-1

Tomoya Hamasaki, Visitor, Ishikawajima-Harima, Heavy Industries Co., Ltd.

ABSTRACT

Ishikawajima-Harima Heavy Industries Co, Ltd., (IHI), was awarded a contract to build a cruise passenger ship which had a superstructure with 4.5mm thick steel plate decks. Since the first time application of 4.5mm to the hull structure was expected to cause a lot of troubles in conjunction with plate distortion, an effort was made to seek and establish the most appropriate standards of design and methods for thin steel plate structure. Structural design and construction methods were carefully reviewed, selected, tested and applied to the ship, and thereby they were verified throughout the actual construction processes. Successful results were obtained from both quality and cost stand points.

INTRODUCTION

In a passenger ship, particularly in its superstructure, a great deal of thin steel plate is applied in order to maintain the ship gravity point as low as possible against its height and thereby to assure a high degree of ship stability. The application of thin steel plates, however, has very significant impact on the degree of distortion and vibration of the structure, both of which could potentially lead a passenger ship to serious quality deterioration. The annoying behavior of thin steel plate can easily destroy the comfortableness of a completed ship, which is attained by having the least vibration, least noise and most admirable appearance of every portion in sight, none of which is allowed to be sacrificed. On the other hand, reduction of fairing work on the thin steel plate structure is always a big struggle for the production department for saving cost and adhering to schedules, the latter of which has a particularly significant impact on painting and outfitting. Therefore, establishing a method to control the behavior of thin steel plates is one of the most essential challenges, both in quality and cost standpoints, for the shipyard which is building a passenger ship.

Although there are many reports regarding the method of thin steel plate processing, each contributing to the improvement of the method, it can also be said that definite conclusions in the cases of 6mm and thinner are unlikely to be obtained.

The cruise passenger ship in question had a superstructure with 4.5mm thick steel plate decks. It was decided to take an advantage of the opportunity to seek and establish the most appropriate standards of design and methods of handling for thin steel plate structure. The primary focus was on minimizing plate distortion with least expenditure possible.

SHIP SPECIFICATIONS

Figure l-a presents an elevation view and figure l-b a typical section of the ship.

The ship is a Japanese shipping company owned oceangoing cruise passenger ship with the classification of NK, Nippon Kaiji Kyokai, and JG, Japanese Government. The principal specifications of the ship are :

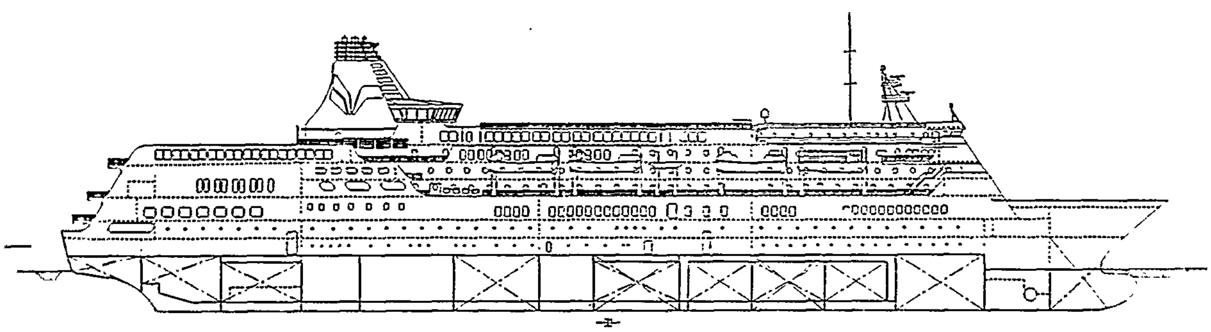


FIGURE l-a. ELEVATION VIEW

Type	Cruise ship
Tonnage	23,000GT, 3,000DWT
Length	175m (574ft)
Beam	24.0m (79ft)
Draft	6.5mm (2lft)
Decks	8
Cruising miles	7,000 n. miles
Main engines	9,270ps IHI-12PC26V x 2
Nav. speed	21 knots
Passengers	606
Crews	120

The building contract was awarded in January, 1989, the fabrication started in July, 1989, and the keel was laid in November, 1989. The ship was launched into the water in January, 1990, and is scheduled to be delivered in July, 1990. The scheduled duration time between the fabrication start and the delivery is 12 months.

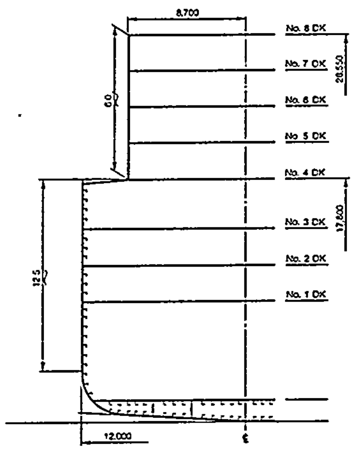


FIGURE l-b. TYPICAL SECTION (IN MM)

DESIGN AND METHODS APPLIED

Figure 2 shows the general approaching scheme that defines areas and matters to be assured in order to attain the least distortion regardless of plate thickness.

In the figure, items in the double boxes are considered to be specially reviewed and improved for the case of 4.5mm superstructure of the ship. Each item was first reviewed empirically at design and planning stages. Experiments were conducted on a case by case basis before the final settlement of design, construction methods and tools/facility applications. The outcome of highlighted design and method applications were monitored closely at each construction process.

A special task force consisting of design and production engineers was formed for this project.

1. STRUCTURE

(1) Block joint

It is widely known that close arrangement of a beam to a block joint will have a good effect on suppressing plate distortion caused by heat of welding at erection. The practical methods to achieve this are summarized:

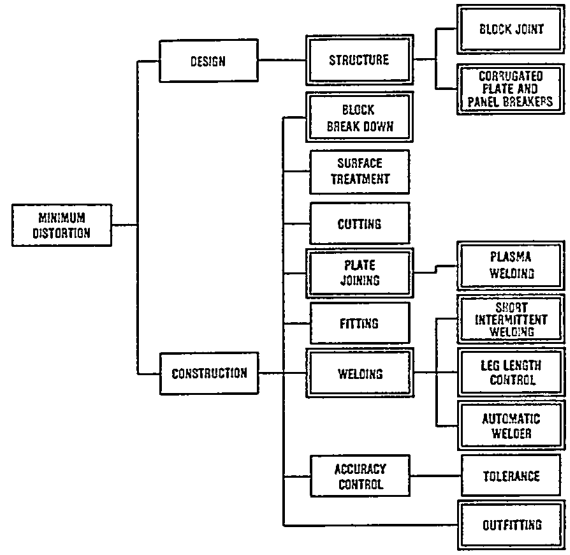


FIGURE 2. APPROACHING SCHEME

a) Locate butt joints where a deck beam runs right underneath.
b) Fit a thick chill plate, 50mm x 22mm, underneath the butt joint, which can also provide counter-distortion restrictions.
c) Locate a beam as close to the joint as possible.

Each one of those methods was carefully reviewed and evaluated considering:

1) The superstructure, in this case, is to stand for longitudinal bending stress equivalent to 80% of that loads on #4 deck.

2) Minimization of hull weight for ship stability assurance.

Methods a) and b) among the above are determined to be applied after experimentations which verified their advantages. Figure 3 shows the sketches of them.

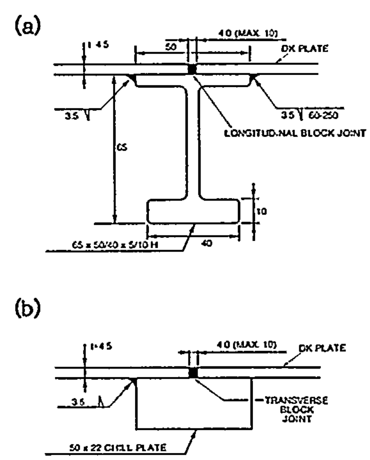


FIGURE 3. BLOCK JOINTING METHOD (IN MM)

Longitudinal joint - The method a) was applied for longitudinal joint. “H” beam was used for a longitudinal beam that runs right underneath joint.

Sectional demensions of the “H” beam were strictly specified in order to maintain the required bending and sheering regidity without weight increase or beam height increase. Dimensions specified were 65mm x 50mm/40mm x 5mm/l0mm, while dimensions of an ordinary longitudinal beam were 65mm x 65mm x 6mm.

Unavailability of standard “H" beam that met these specifications resulted in a joint effort with a steel manufacturer. It was not very long until obtaining the NK approval of the new product. .

Figure 4 shows the jointing method of “H” beams at transverse joint.

Transverse joint - Method b) combined with c) was applied for transverse joints. Figure 5 illustrates a typical application of the method. The block joint was set 350mm off a transverse beam on the preceding block. Flat bars were installed 350mm off the joint on the following block.

An alternative method a) was eliminated in the case of transverse joints because of the tremendous increase of additional brackets which hold longitudinal beams on both sides of a transverse beam, figure 6.

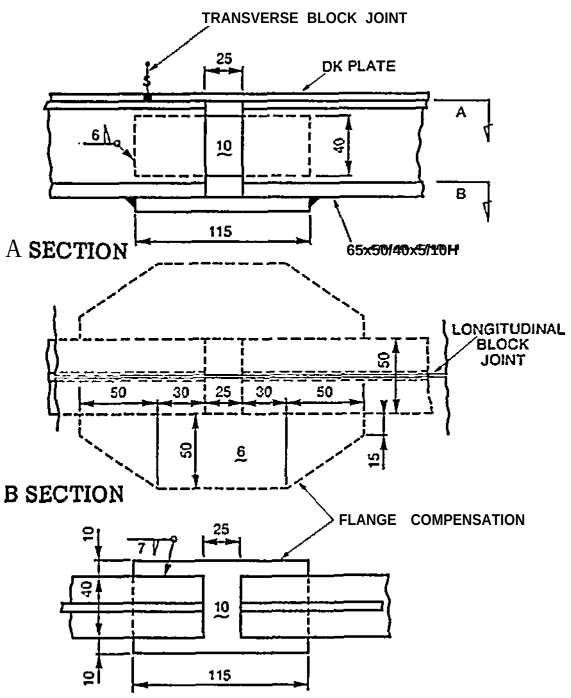


FIGURE 4. “H” BEAM JOINTING METHOD (IN MM)

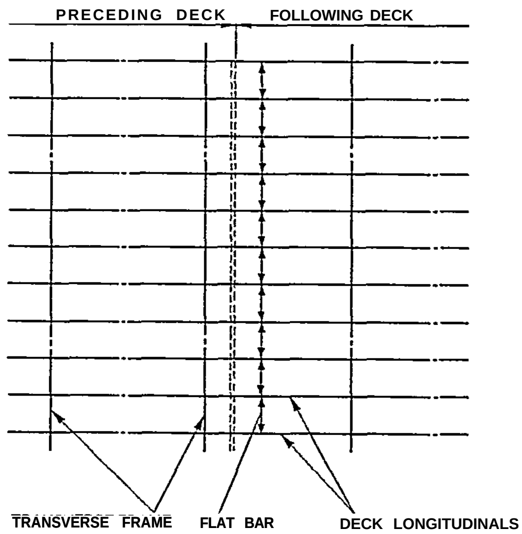


FIGURE 5. TRANSVERSE JOINTING METHOD

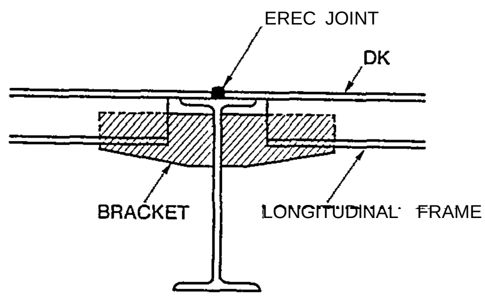


FIGURE 6. METHOD (a) APPLICATION AT TRANSVERSE JOINT

(2) Corrugated plate

Adoption of corrugated plate to compartment partitions provides a big advantage in distortion control because of less heat input compared to flat plate assembly. Corrugated plate was designed to be applied as much as possible where the following conditions are assured.

a) Not to be transverse structural members.
b) Plate thickness is 4.5mm
c) Partition length is 2.lm long or more so that at least 3 ridges can stay on. (ridge space of corrugated plate : 0.7m)

70% of the compartment partitions in the entire ship were satisfactory to the conditions. This resulted in a total of 2000m long, 220tons, of corrugated partitions.

Figure 7 shows the typical profile of a ridge,

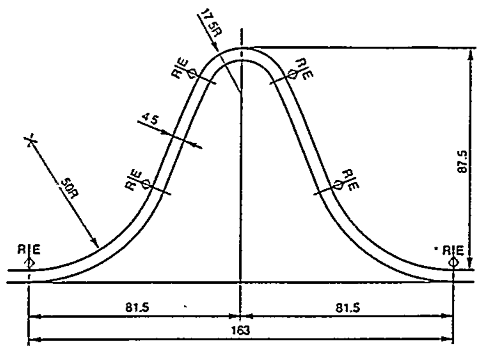


FIGURE 7. RIDGE PROFILE (IN MM)

(3) Panel breakers

Besides restricting welding heat input, installing panel breakers' is also an effective means of controlling distortion on thin steel plate. 'Panel breaking' is an arrangement of breaking panel down to smaller ones by installing flat bars, and thereby gaining stiffness of an entire panel.

Reinforcement of the public space deck was a typical application of panel breakers. Compartments near the engine room, the biggest source of vibration, were also reinforced in order to eliminate resonance by changing the characteristic frequency of each panel.

The application details of flat bars were determined after conducting experiments on model blocks. The following matters were affirmed:

a) Minimization of installation manhours.
b) Line welders are to be applied to longitudinal beams even in the case flat bars are installed before beams.
c) Not disturbing heat insulation work.
d) Obtaining prescribed characteristic frequency.

A flat bar has 3.5mm leg length of continuous-one-side-welding with both ends unwelded, with no snips on the corners. The line welder's paths were secured by installing the flat bars with a distance of 70mm at each end from a longitudinal beam. Since the depth of a flat bar, 32mm, was smaller than the insulation thickness, no swelling up of insulation at a flat bar was necessary. Figure 8 presents the detail of a flat bar installation as a panel breaker.

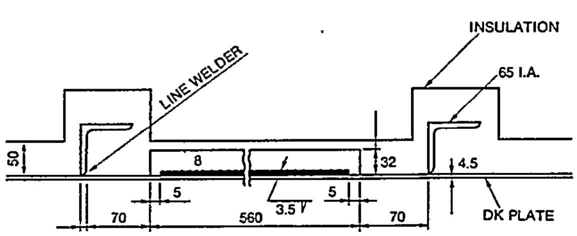


FIGURE 8. FLAT BAR INSTALLATION DETAIL

2. CONSTRUCTION METHODS

(1) Block break down

The types of distortion previously discussed are local distortion, and usually Occur at the sub-assembly and assembly stages. The other type of distortion that occurs at the erection stage, which extends over a wider range than local distortion, needs another approach.

Distortion at the erection stage is considered to be caused mainly by heat of welding at an erection joint. Moreover, the welding method with the least heat input at erection is empirically down hand welding. Three principal ideas of block break down were brought up for review. Talbe 1 lists merits and demerits of each idea.

Figure 9 presents a section view of the block break down that was settled upon. The superstructure consisted of three grand assembled blocks, port, center and starboard, each of which held four decks in it. "F" shaped blocks on both sides characterized the block break down of the ship because it made it possible to apply down hand welding in full scale. The total length of a flat block was limited to 13m maximum for better handling.

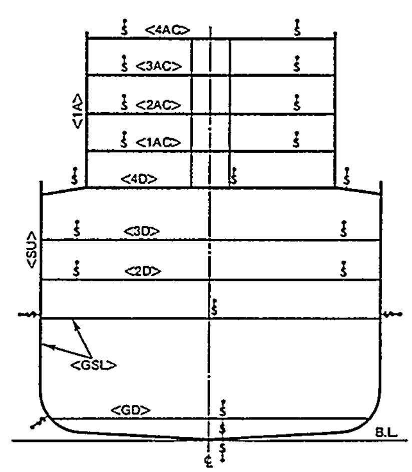


FIGURE 9. BLOCK BREAKDOWN

(2) Welding (beams and stiffeners to plate)

Controlling heat input is a fundamental approach of the welding methodology used for distortion control in the processes of thin steel plate construction.

Short intermittent welding - This was applied to decks #5 and above. Figure 10 shows the sketch. 75mm beads were applied at intervals of 350mm by a modified line-welder which is a semi-automatic CO2 welding machine.

Leg length **control** - In commercial ship construction, leg length of the welding bead, which is an indication of the amount of deposited metal, tends to be 30% to 40% more than that designed. As extra deposit is a formidable cause of distortion, so full application of automatic welding method was investigated and subsequently implemented.

Modification of automatic welder - Methods most commonly applied to small deposit welding with 4mm and less leg length are:

* Small rod gravity welding method.
* CO2 semi-automatic welding method (Line welder).

The CO2 semi-automatic welding method reduces heat input with its higher welding speed, as opposed to the gravity rod.

This time, a modified version of a line welder was developed through trials on model blocks. The modification proved a satisfactory result of the required automatic intermittent welding and sound penetration at both ends of a bead. The specifications of the modified line welder are:

* Welding speed	400 to 1,250mm/min
* Driving motor	DC24V 15W
* Unwelded end	85mm
* Angle sizes applicable	65 to 75mm, 90 to 300mm
* Dimensions	320mmW x 180mmLx 260mmH
* Weight	8kg
* Special functions	intermittent welding, simultaneous weld at both sides

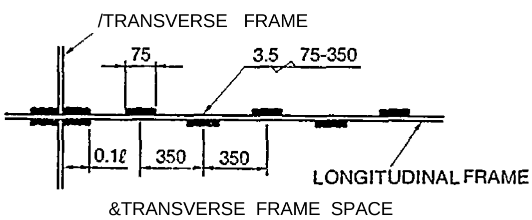
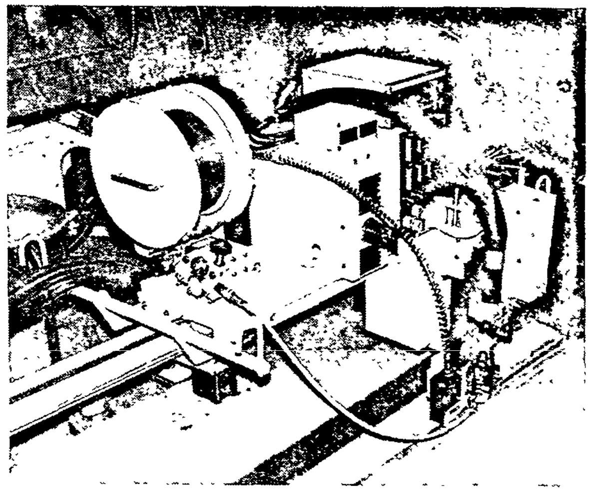


FIGURE 10. SHORT INTERMITTENT WELDING

(3) Plate joining

The plasma arc welding method was applied for the plate joining process of the assemby stage. An automatic plasma welding machine was used, figure 11, which was developed under the three year joint effort with a welding machine manufacturer. Fugure 12 illustrates the drastic reduction of deposited metal. The machine provides the following features.

a) Capable of welding thin plates, mild steel or high-tensile-strength steel, with 2.3mm to 6.0mm thick.
b) Welding control with visual sensing and real time feedback.
c) Applicable to the "I" shaped groove with 0.5mm to 2.0mm gap.
d) The amount of distortion is approximately l/8 of that experienced with the conventional MA-welding method. (figure 13)



TYPYCAL CONDITIONS (THICKNESS : 6MM)

Center gas $H_2$7%, Ar93% (ℓ/min)	Shielding gas Ar100% (ℓ/min)	Welding current			Wire feeding speed (cm/min)	Welding speed (cm/min)
		Base (A)	Peak (A)	Frequency (Hz)		
2.2 ~ 2.4	15	120	280	500	140 ~ 160	25 ~ 30

FIGURE 11. AUTOMATIC PLASMA WELDER

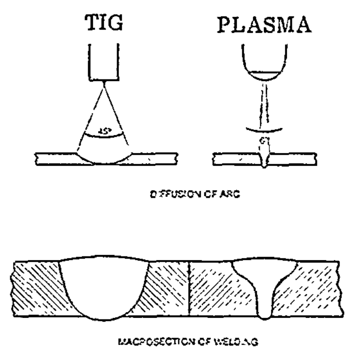


FIGURE 12. PLASMA AND TIG

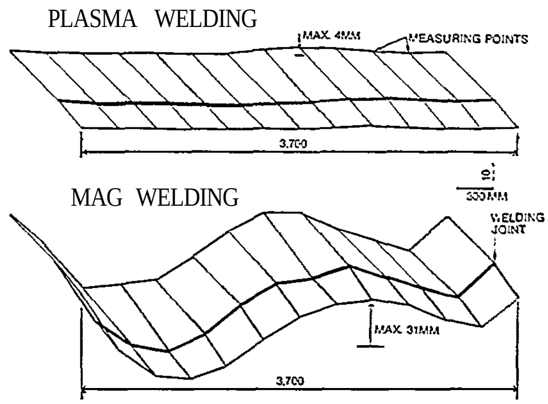


FIGURE 13. DISTORTION COMPARISON (6MM THICK PLATE WITH I-GROOVE JOINT)

Table 1. Block break down methods

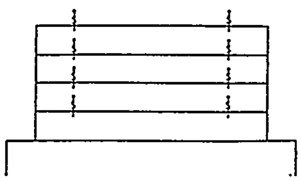
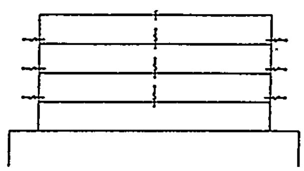
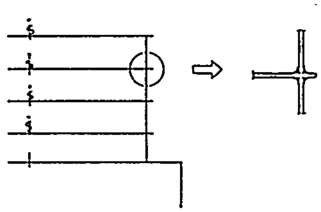
Type	Configuration	Merit and Demerit
F		(Merit) Provides down hand welding. (Demerit) Increases onboard connections of pipes running P-S.
L		**(Merit)** Decreases onboard connections of pipes running P-S. **emerit)** **Increases horizontal welding length and total erection welding length.**
U (L)		**(Merit)** Provides down hand fillet welding. **(Demerit)** Worsens smooth appearance of outside wall.

Table 2. Outfitting guide lines

1. Pipe support installation onto skin plate.
   1) Avoid direct installation onto skin plate without beams or flat bars on the other side.

   2) Exceptional cases;
      * On deck plate where deck composition covers later.
      * On compartment partitions.

2. Doubler plate fitting.
   Fit doubling plate at every foot of support that is installed onto skin plate.

3. Deck or bulkhead penetrations.
   Apply sleeve type penetrations rather than flange type as far as possible.

4. Welding.
   Apply welding rods of 2.6mmø or 3.2mmø unless otherwise specified.
   Maintain leg length of 3.5mm or less.

(4) Outfitting

A model block was also dedicated to conducting tests to establish guide lines of outfitting work on thin steel plate. Plate distortion was measured through processes of burning and welding penetrations as well as installation of the other fittings directly attached to the plate surface.

Burning - Roth propane-gas burning and plasma burning were tested. Plasma burning showed its advantage, specially in the case of burning several holes adjacent to each other. Plasma burning was subsequently adopted to the ship.

Closing holes - A comparison between overlapping (with fillet welding) and inserting (with butt welding) was made. Inserting was proved to be advantageous due to its less welding length.

Pipe support installation - 3mm maximum distortion was found due to welding around pipe support (50mm x 50mm angle steel) to plate surface. No significant redution of distortion was seen by inserting a doubler at foot of a pipe support.

Examples of established outfitting guide lines are presented in table 2.

VERIFICATION

Each method under consideration for application to the ship construction was first verified experimentally on model blocks in order to make sure it worked.

Throughout the hull construction processes, distortion on every hull block was measured and statistically analyzed for the evaluation of methods and for further improvement.

Immediately after the completion of hull structure and engine room outfitting, the ship cruised, under self propulsion, 300 nautical miles on the sea on its way to the pier where it was planned that the joiner work would be completed. This is called “the steel trial.” The task force took the full advantage of this opportunity by measuring vibrations on uncovered bulkheads and decks.

CONCLUSIONS

Although, at the submittal of this paper, the ship is not yet delivered, it can be said that the task was very successful.

Fairing manhours per square meter in the ship were 37% less than that obtained in a ferry boat constructed in 1989. This is quite satisfactory because the ferry boat had similar principal dimensions as the passenger ship, and had a superstructure constructed mainly of 6mm and 7mm thick plate. The improved fairing manhours per square meter has greatly encouraged releasing compartments to painting and outfitting just-in-time. This has been of course the greatest contribution to achieving quality satisfaction, schedule adherence and cost reduction.

The vibration measuring during the steel trial resulted only in a few additional local reinforcements onto the structure.

The most remarkable items that will contribute to suppressing plate distortion are summarized:

1) 3.0mm to 3.5mm of fillet leg length was successfully obtained.
2) An "H" beam right underneath a joint was proved to be effective.
3) Plasma arc welding is, at present, the most effective welding method for joining plates with 6mm and less.

We have been successful in obtaining valuable outcomes for thin steel plate construction practices. However, it is also true that we were not able to resolve the big questions that came up among the task force members, “why does it have to be 4.5mm?,” "why can’t 5.0mm with less beams or flat bars be an alternative?” The next challenge is to seek the ideal combination of plate thickness, longitudinal beam space, transverse beam space, and block breakdown.

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